Disclaimer: Products and companies mentioned in this presentation are not endorsed by the author, CP or NCLT.

It's A **Nano** World After All:

using nanotech consumer products to engage student learning

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Cal Poly, SLO

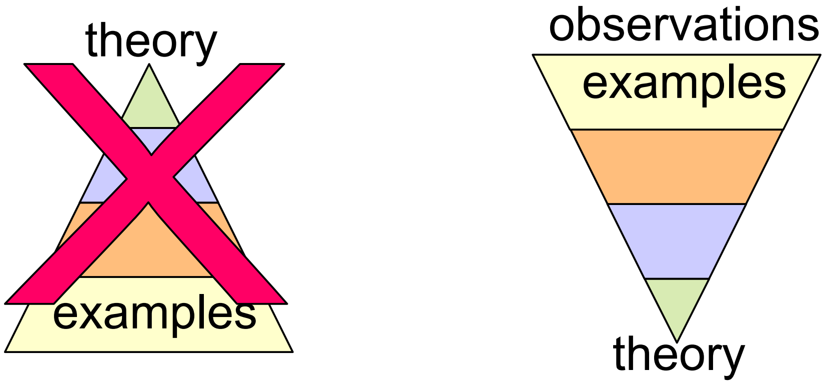
National Center for Learning and Teaching in Nanoscale Science and Engineering

Teaching Nanotechnology

Opportunities for learning science

"Hook" (relevant applications) to engage learning

- give examples **upfront** rather than at end



- pique interests and questions

Be a more informed consumer with critical thinking!

Nanotechnology Products

- Is there a true materials performance advantage or is it just marketing hype?

-Is the advantage just a performance enhancement or a *unique* product trait?

- Could the same technology be used for other applications?

- How much would you pay for a product of nano?

Caveat Emptor!?

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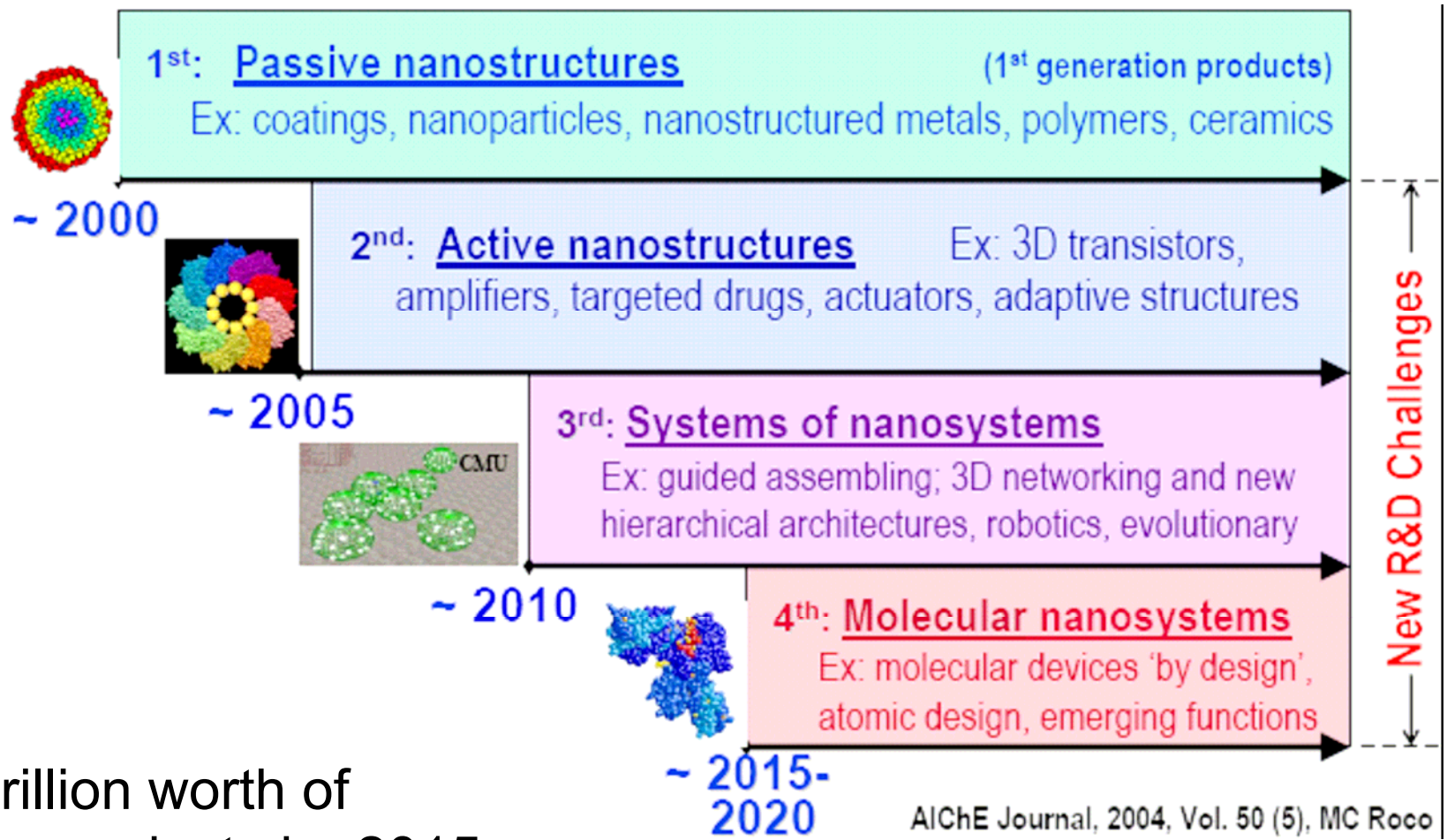
Nanotechnology Applications

Has anything "useful" come out of nano research?



$1 trillion worth of nano products by 2015
- NSF estimate, Lux Research

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Nanotechnology Applications

What **nano** products are out there right now?

Clothing, Fabrics

Cosmetics, Sunscreen

Sports

Cleaning products

Coatings

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Car Wax

Microemulsion of tiny particles of Carnauba wax and proprietary polishing **nanoparticles**

Eagle One Nanowax

- smoother coating minimizes smearing, allows light to reflect more evenly to give deep, glossy shine
- easy to remove, no white residue
- nanoparticles fill fine scratches and conceal swirl marks to create a more even surface

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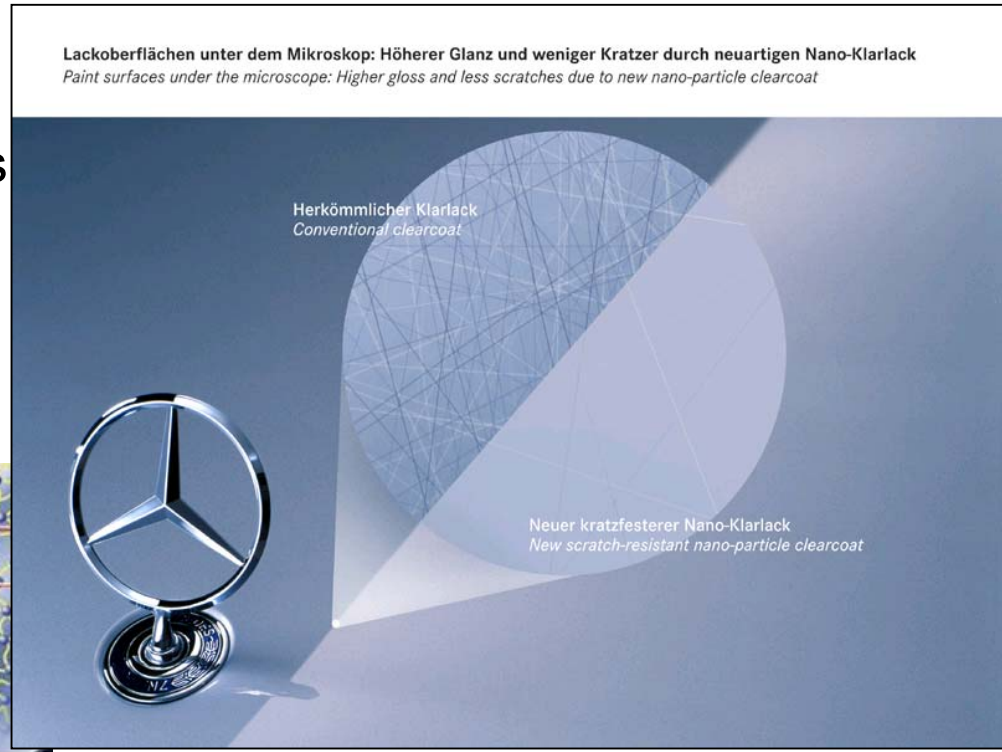
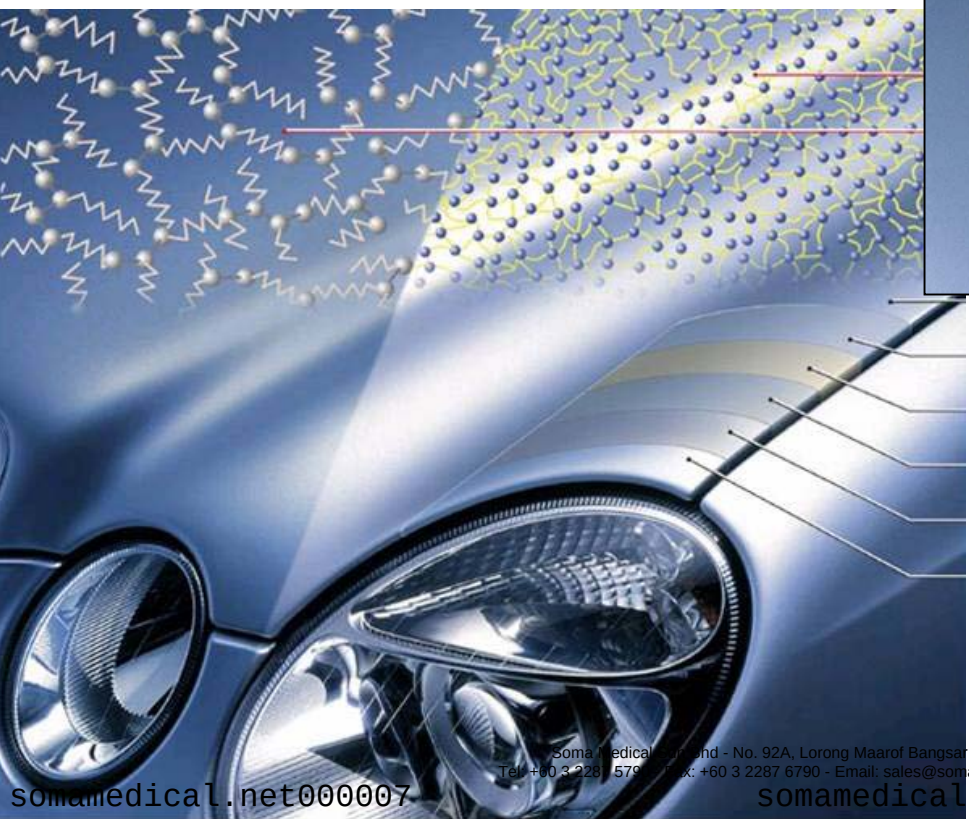
Mercedes-Benz Clearcoat

- scratch resistant
  protects against mechanical washes
- enhanced, long-lasting gloss
- weatherproof barrier





Ceramic **nanoparticles** harden in paintshop oven to form an extensive cross-linked network

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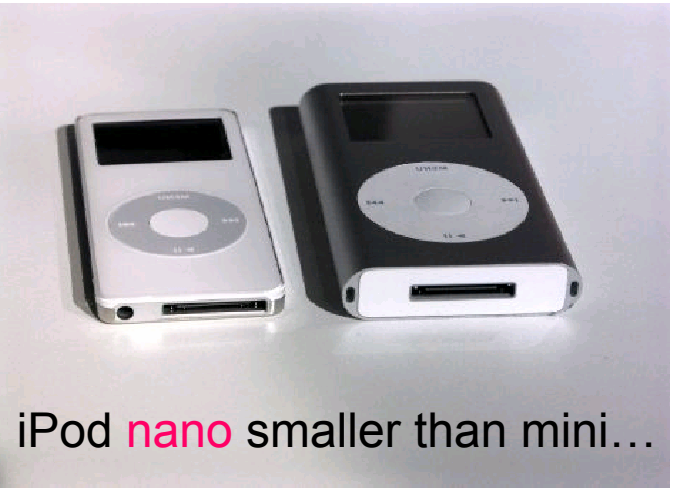
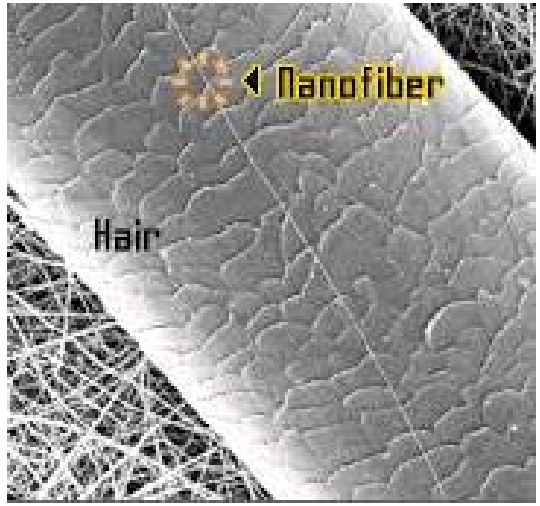
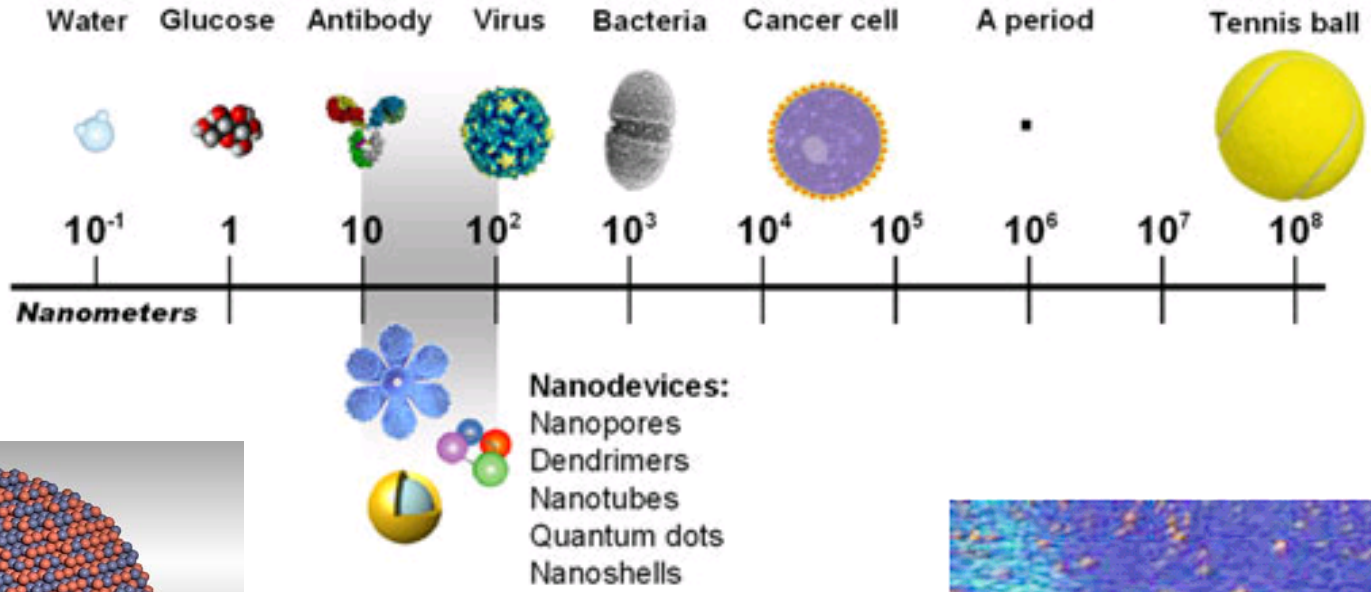
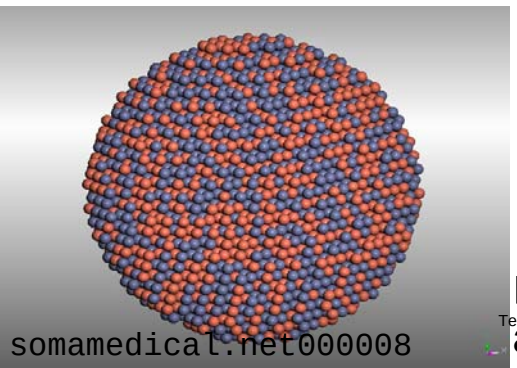
Size and Scale



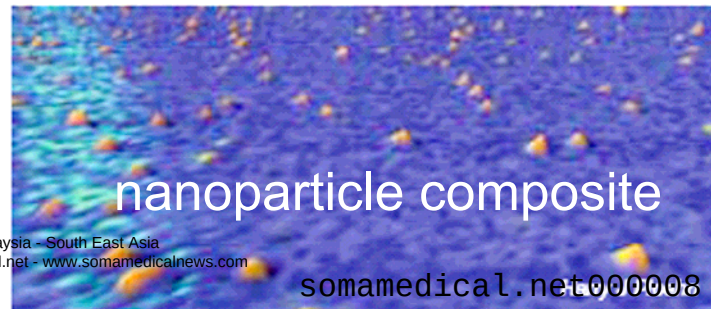
$1\ nm = 10^{-9}\ m$







nanoparticle: aggregate of atoms



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Sunscreen

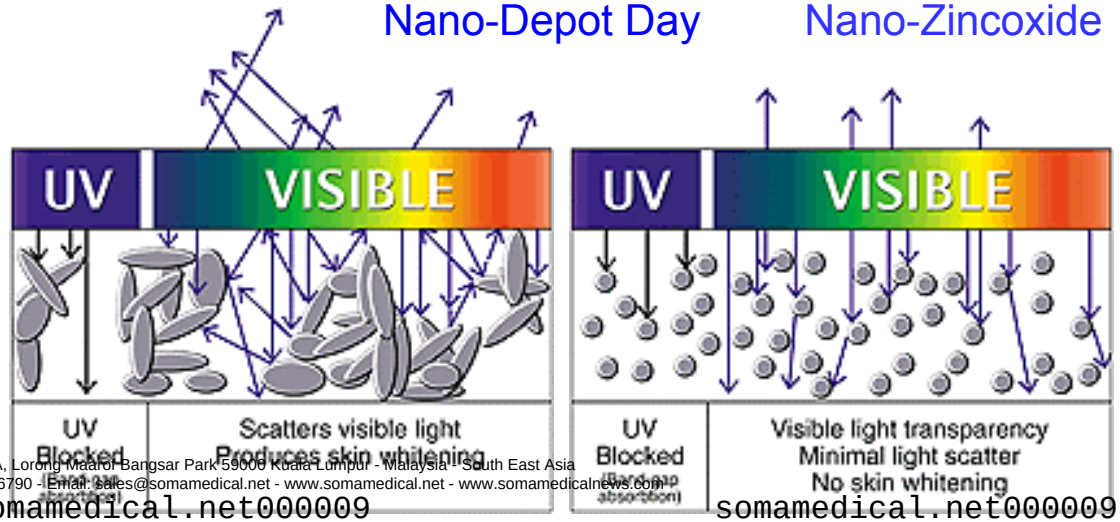
Nano-dispersed zinc oxide (30 nm) provides protection against UVA and UVB rays and is transparent

- cosmetic clarity (no pasty white look)
- higher SPF ratings
- nongreasy, easy application

Grandel PR Vitamin Nano-Depot Day

Keys Solar Rx Nano-Zincoxide

Wet Dreams sunscreen with ZinClear ZnO



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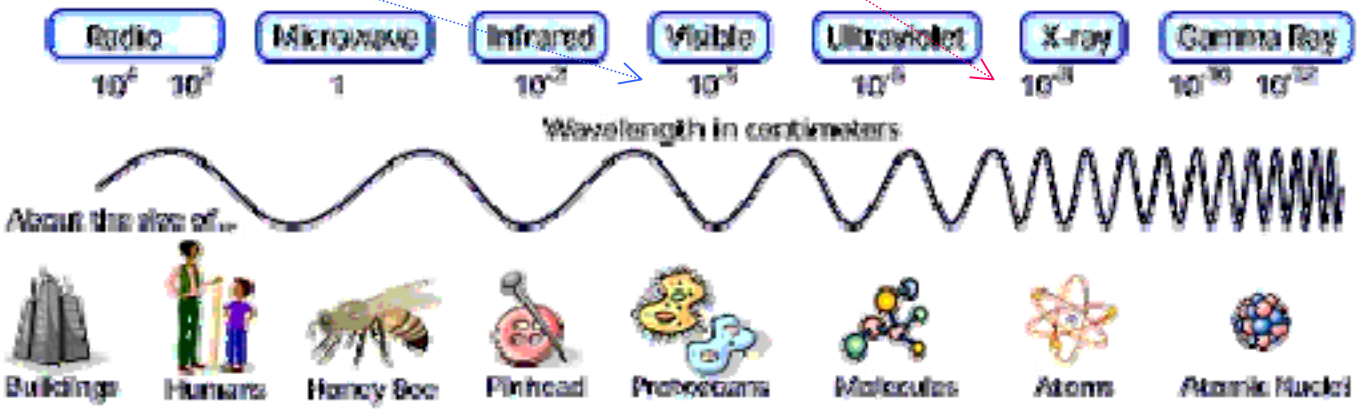
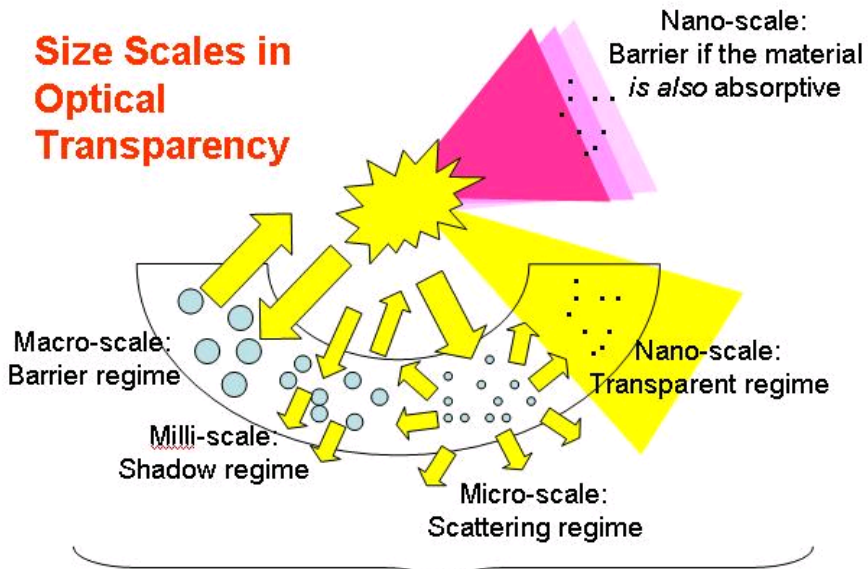
Optical Properties of Nanoparticles

particles on the nanoscale are too small to scatter visible light and appear *transparent* to the naked eye





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Cosmetics

Nano-capsules (200 nm) contain active ingredients and can easily penetrate skin

- delivers Vitamins A, C, & E, or pro-retinol A
- more effective means of delivery than emulsions
- goes on light and sheer; no residue
- affects skin at the “molecular level”

zinc oxide nanoparticles
for UV protection in
Olay Complete

BIONOVA
NANO SKIN TECH

L'ORÉAL
PARIS

nanosomes (small liposomes)
in L'Oréal Revitalift

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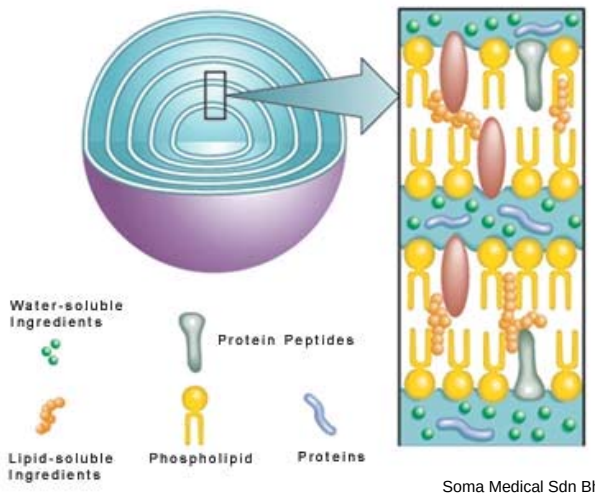
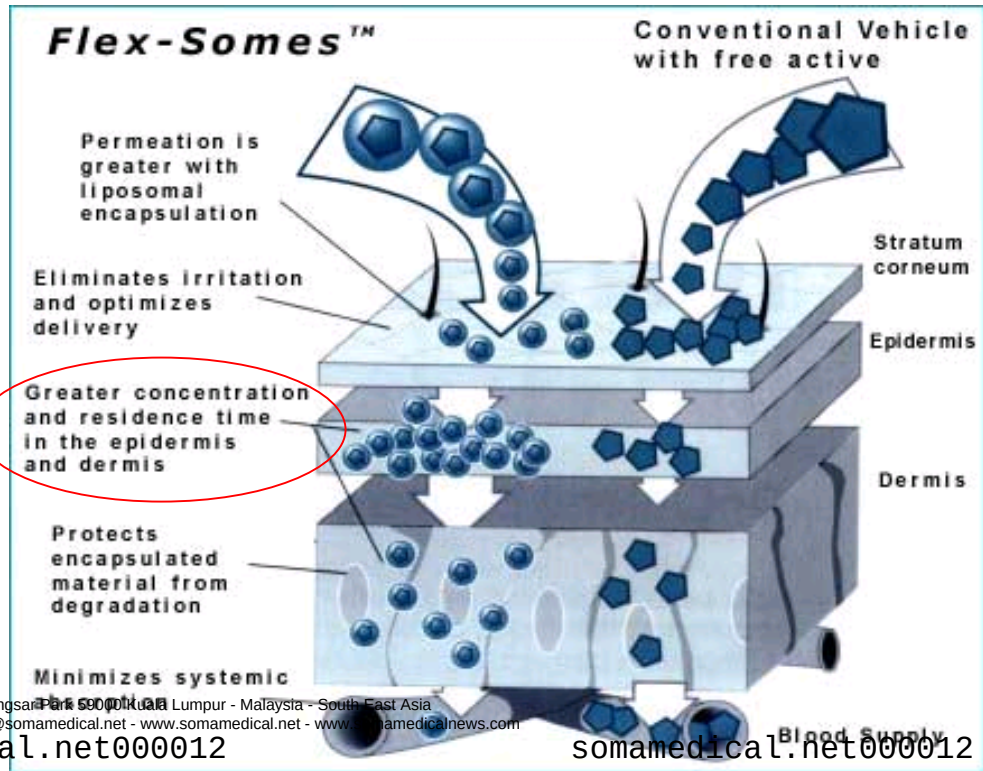
Muscle & Joint Pain Cream

Flex-Somes™, **nano-liposomes** (90 nm) to deliver medication

- encapsulates nutrients and pharmaceutical ingredients
- delivers active ingredients to the lower layers of the skin (topical rather than oral delivery)
- provides deep and quick delivery for faster recovery





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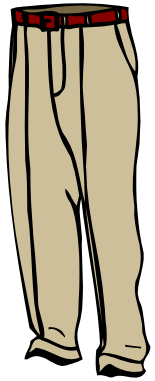
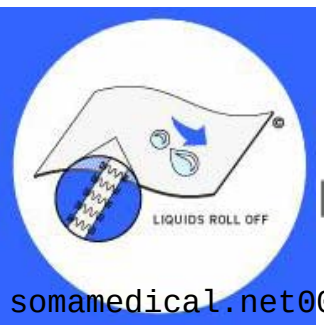
Fabrics



- spill proof
- stain resistant
- wrinkle free

Billions of **nanowhiskers** (10 nm long) create a thin cushion of air above the cotton fabric, smoothing out wrinkles and allowing liquids to bead up and roll off without a trace.



NANOtex™
Fabric to the Next™

Levi's Dockers Go Khaki with Stain Defender

Eddie Bauer's Nano-Care chinos

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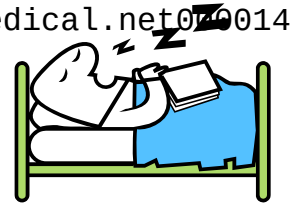
Bedding



Nano-Tex™ **nanowhiskers** create a semi-impervious layer that traps fluids and particles so they can be removed and washed away

Simmons HealthSmart Bed Mattresses

NANOtex™

Resists Spills

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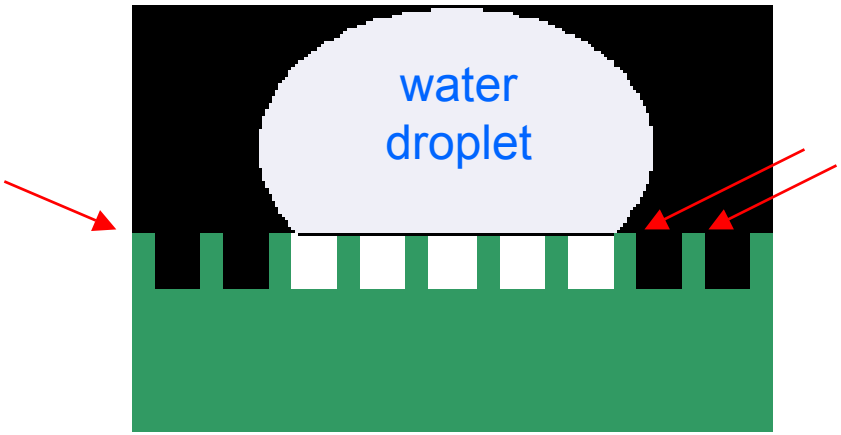
Water repellent surfaces in Nature



many small tubes or whiskers keep water and solid at minimal contact for superhydrophobia (extreme water repellency)

peach fuzz and the lotus leaf as inspiration

Surface Coatings

Nanoparticulate coatings make surfaces superhydrophobic (extremely water-repellent) and self-cleaning

- reduces contact area between water and surface to a minimum
- decreases the forces of adhesion; water droplets assume globular form
- dirt particles rinsed away
- surfaces stay clean for a long time

BASF Mincor™ superhydrophic coating

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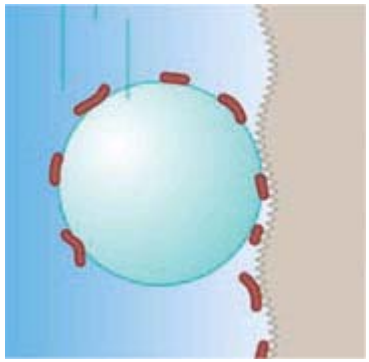
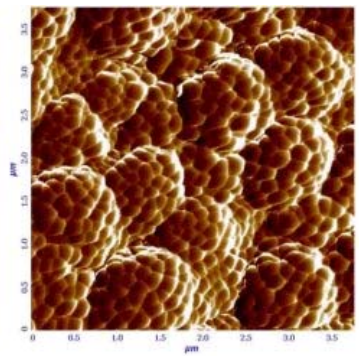
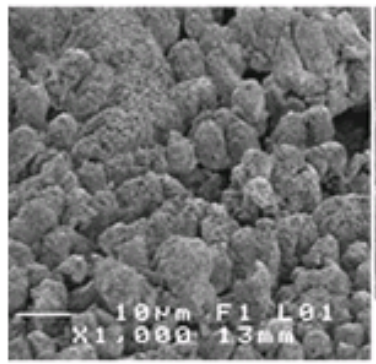
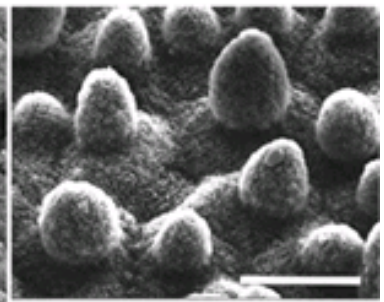
Self-cleaning Surfaces



- water droplets form spherical globules
- rough nanoscale surface picks up dirt
- water and dirt roll off
- biomimicry





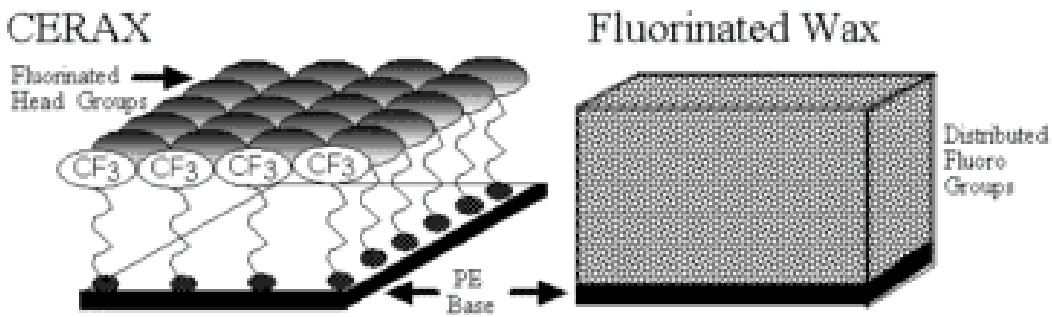


Left: SEM image of surface produced within the project.
Right: SEM image of the surface of a Lotus leaf.
(D. Chakarov, P. Holgerson)

Ski Polymer (“Nanowax”)

Self-assembling fluoride (CF_3) polymers and multifunctiontal **nanoparticles** create lamellar (thin layer) structure on skis and snowboards

- superior adhesive behaviour more resistant to aggressive types of snow and minimally responsive to temperature
- hard, highly fluorinated surface gives excellent gliding ability



CERAX Racing Polymer

Nanogate Coating Sytems GmbH

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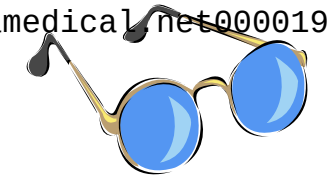
Sunglasses



Nanocoating on eyeglass lenses:
antireflective polymer coating
(3-10 nm) self assembles

Hard and strong coating:

- excellent scratch, chip resistance
- resistant to dirt and moisture
- anti-reflective

Native Eyewear Nano Sunglasses
With Nanofilm coating

NANOFILM
Designing thin films

NATIVE
ALL SPORTS ALL POLARIZED

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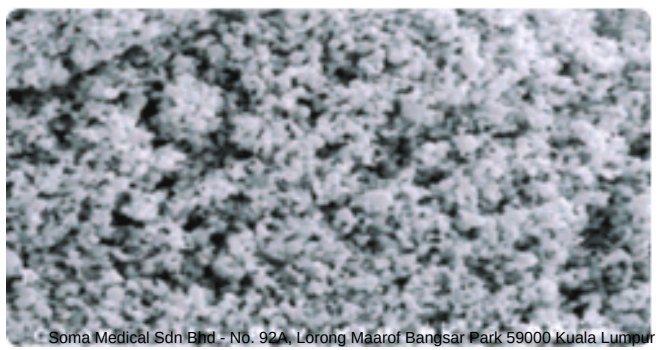
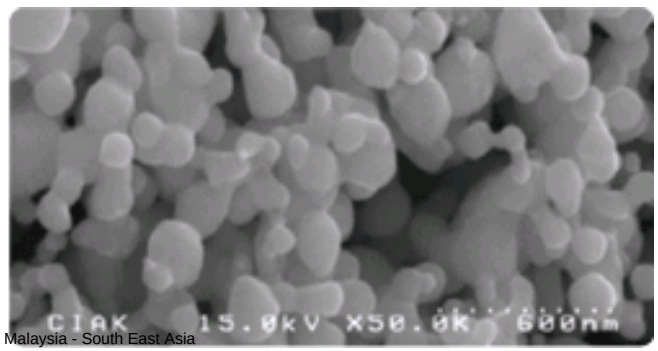
Odor-Free Socks

Silver **nanoparticles** embedded in the fibers of socks

JR Nanotech SoleFresh Socks

- odor-free, antibacterial
- silver naturally antibacterial and antifungal
- large surface area achieved with nanoparticles





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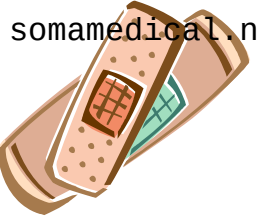

Wound Dressing

Large surface area of **nanosized** silver particles improves anti-bacterial effectiveness

- faster recovery times
- bacteria killed quicker with nano-particles than with other silver forms

Curad silver bandages

Nucryst Acticoat dressing for burns

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Appliances

Nano-sized silver particles (1-100 nm) coat the interior of refrigerators, washing machines, and filters of air conditions, air purifiers and vacuum cleaners

RS-21DLMR refrigerator

AS-24S6GB air conditioner

HA-1435A washing machine

- stops growth of fungi and bacteria
- resistant to odor-causing bacteria
- keeps food fresh longer

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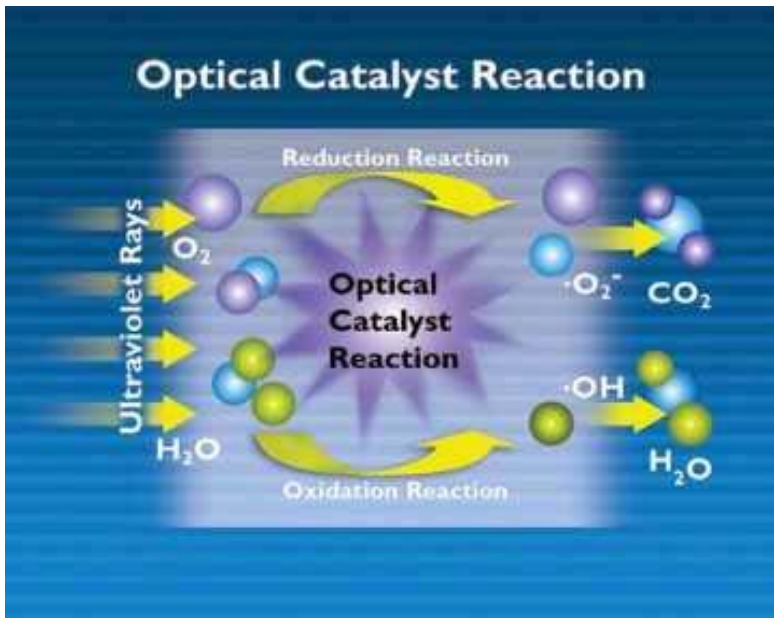
Air Purifier

NanoBreeze
Room Air Purifier

TiO_2 nanoparticles (40 nm) convert organic pollutants to CO_2 and H_2O through oxidation by photocatalysis

NanoBreeze
Car Air Purifier



- no filters or collection plates
- does not produce ozone
- decomposes airborne contaminants, VOCs (volatile organic chemicals): allergens, odors, germ, gases, smoke, fumes, etc.
- destroys microbes and bioaerosols (dust mites, mold spores) by disintegrating their DNA

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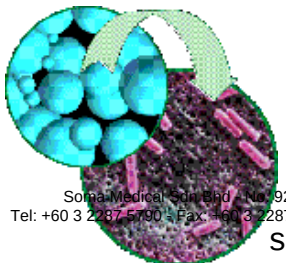
Disinfectant

Nanoemulsion of oil droplets **nanospheres** (~170 nm) in water adhere to bacterial cells and kill microorganisms

- nanospheres carry surface charges that efficiently penetrate the surface charges on microorganisms' membranes
- large surface area of nanospheres requires only miniscule amounts of the biocidal compound PCMX (0.2% vs. 3-5%)
- targets tiny bacteria and viruses, but not larger human cells
- effective and **non-toxic** (gloves & mask not needed)
- used on cruise ships and airplanes



EnviroSystem EcoTru

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nanoemulsion disinfectant

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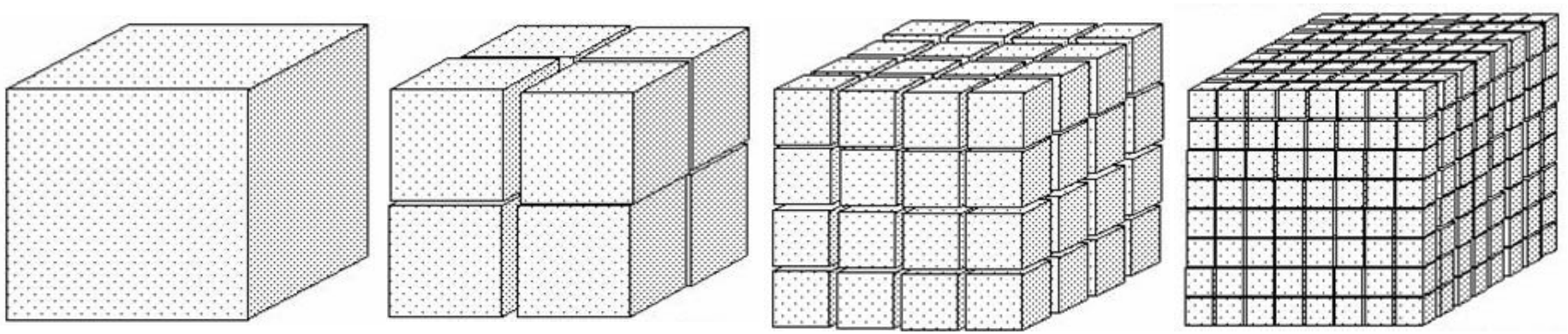
Surface Area/Volume: size effects

Nanoparticles offer HUGE amounts of surface area!



As the object size gets smaller, the surface area to volume ratio becomes larger.

- nanoparticle surfaces act as excellent catalyst sites
- less amount of material needed for same effect

→ *high efficiency, less toxicity, less weight, and/or less cost!*

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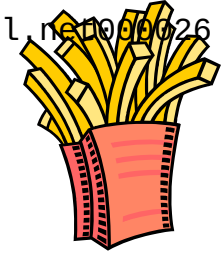
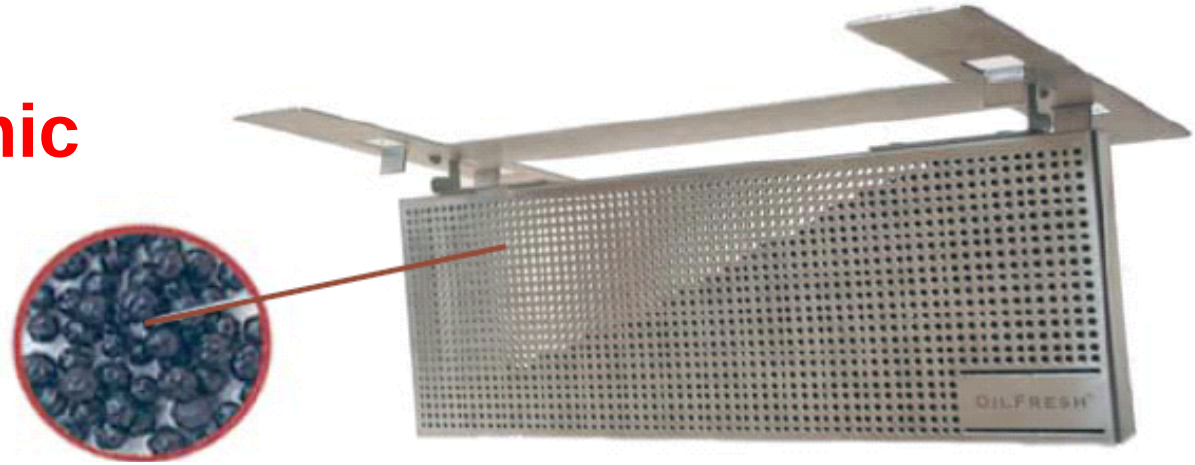
Catalytic Device

antioxidation of deep-frying oil



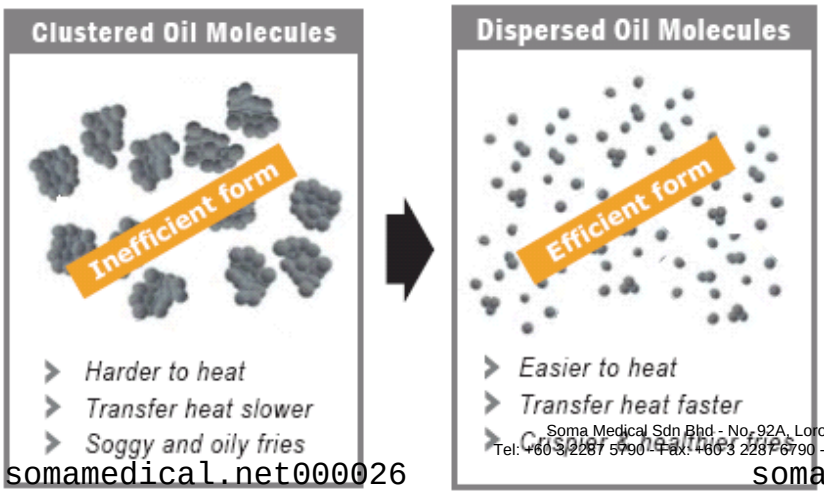
Porous **nanoceramic** catalytic pellets contain silver



Nanoceramic pellets

OilFresh Antioxidation Device

large surface area prevents oil from oxidizing and clumping:



- enhanced heat conduction
- eliminates foul smells (ionized Ag)
- eliminates redundant fatty remnants (healthier fries!)

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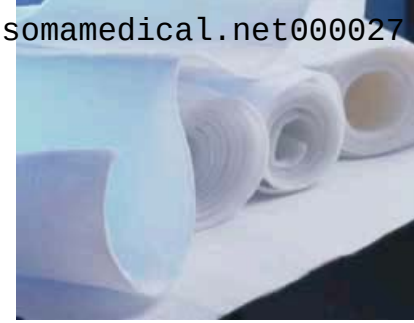
Footwarmers



Nanoporous lattice structure for low weight insulation

open-celled structure with very high surface area and billions of irregularly shaped pores (2-50 nm):

- high insulation efficiency
- very light weight

Aspen Aerogel (Pyrogel AR5401)
Shock Doctor HotBeds

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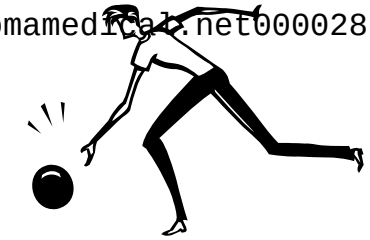
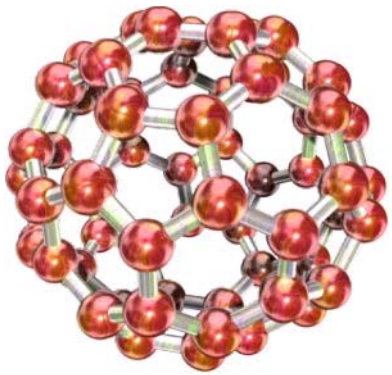
Bowling Balls



Fullerenes or **Buckyballs**
in super-hard coating

- prevents chipping and cracking
- resists surface nicks
- straighter ball performance



Japanese company Nanodesu
"It's nano!" bowling balls

NANODESU

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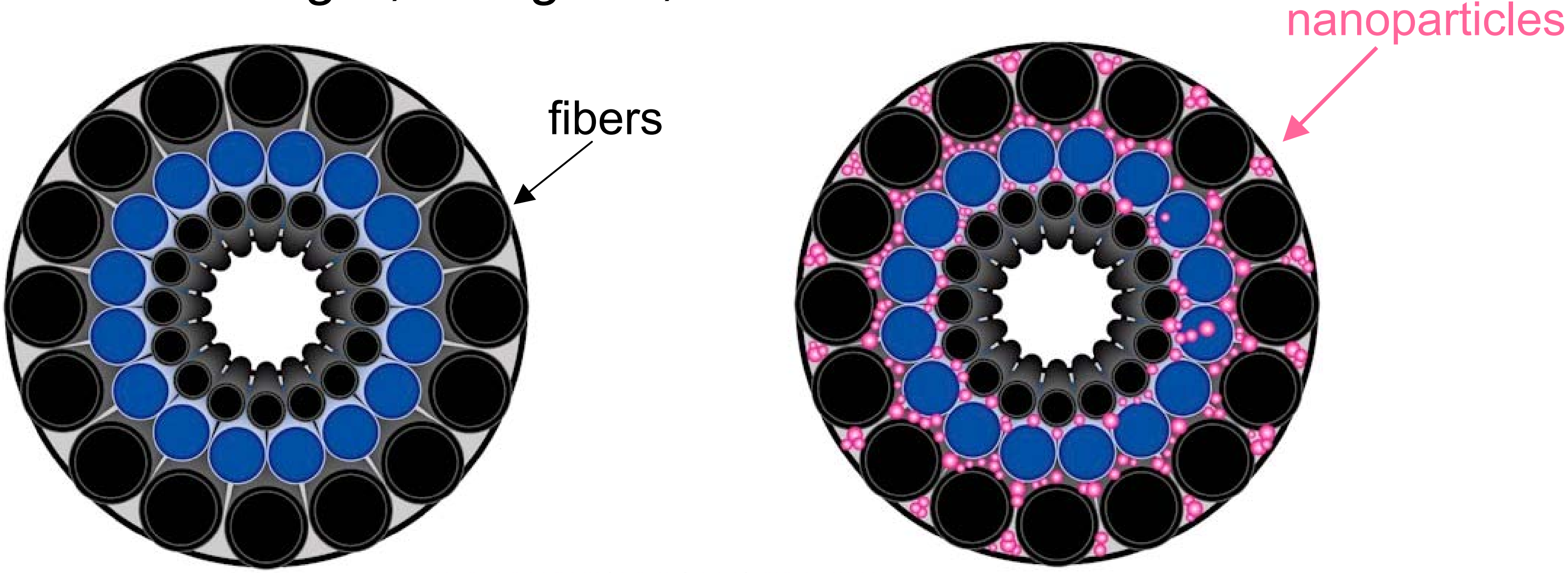
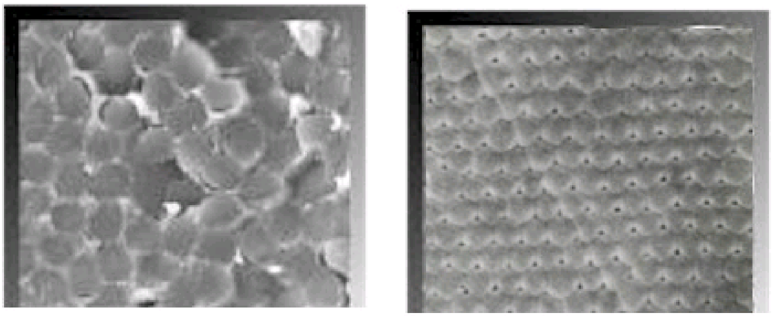
Golf Club Shafts

Nanoparticles within fiber reinforced composites

AccuFLEX shafts: *"longer, straighter, more consistent"*



Example of the "tighter" structure
of the NANO vs Other, under Magnification



Standard "high density" Graphite

Nano Technology

EVOLUTION NanoComposite

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Golf Club Shafts and Heads

Nanoparticles reinforces carbon (graphite) composite material

Wilson Nano-Technology Crown:

- high strength and low density
- improved torsion stability (longer, straighter shots)

Carbon **nanotubes** in club heads

Wilson Clubs Dd5 Pd5 FwC:

- reduced weight (thus faster club head speed)

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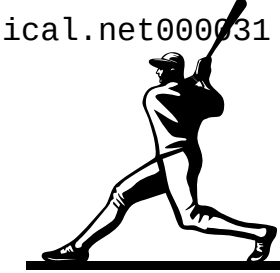
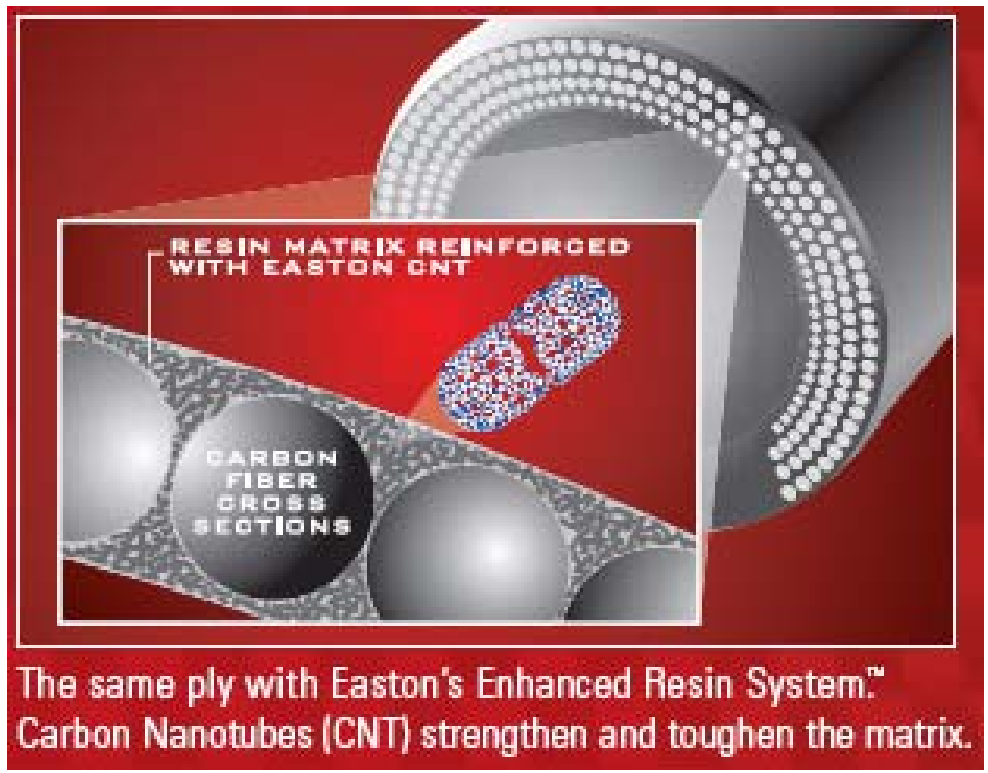
Baseball Bats



Carbon **nanotubes** within carbon fiber composites

Easton Stealth CNT bats

- improved strength in resin area with Zyvex nanotubes
- greater strength/density



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Tennis Racquets

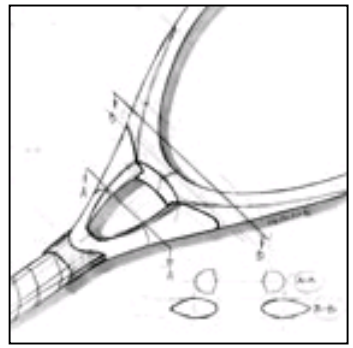
Nanosized SiO_2 within voids of carbon fibers

nCODE POTENTIAL. UNLOCKED

Wilson nSix-One Tour racquet:

- greater strength, stability, power

Roger Federer 2004 Wimbledon



Carbon **nanotubes** around racquet head

Babolat's VS NCT (Nano Carbon Technology):

- greater stiffness, flex resistance, rigidity
- lightweight, responsive
- larger sweet spot

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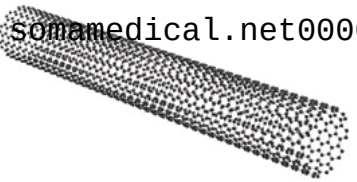
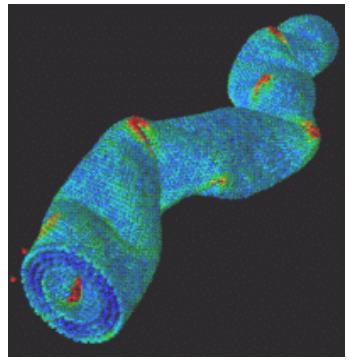


Carbon Nanotubes

cylindrical carbon tube, diameter ~1 nm

high stiffness and strength:

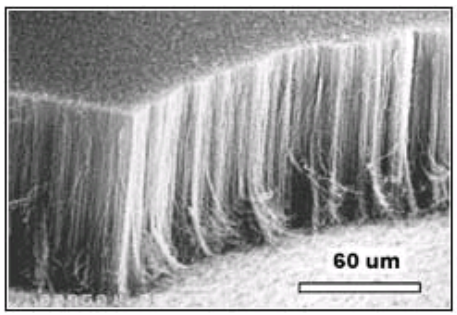
- Tensile strength = 63 GPa (16X stronger than steel)
- Young's modulus = 1 TPa (theoretical)

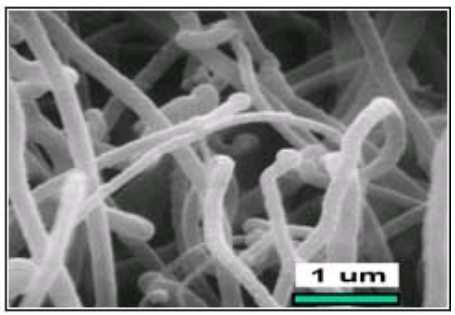


highly flexible

good thermal and electrical conductors

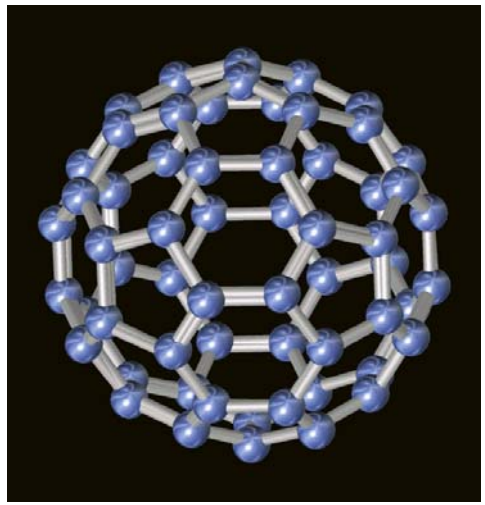
can increase toughness and lower density in composites





Buckyballs or Fullerenes

C_{60} sphere, diameter ~0.4 nm



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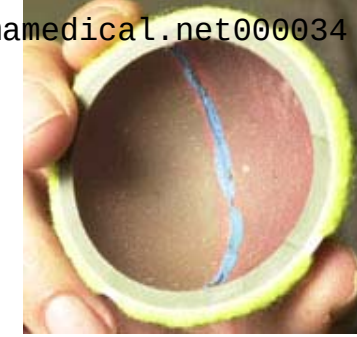
Tennis Balls

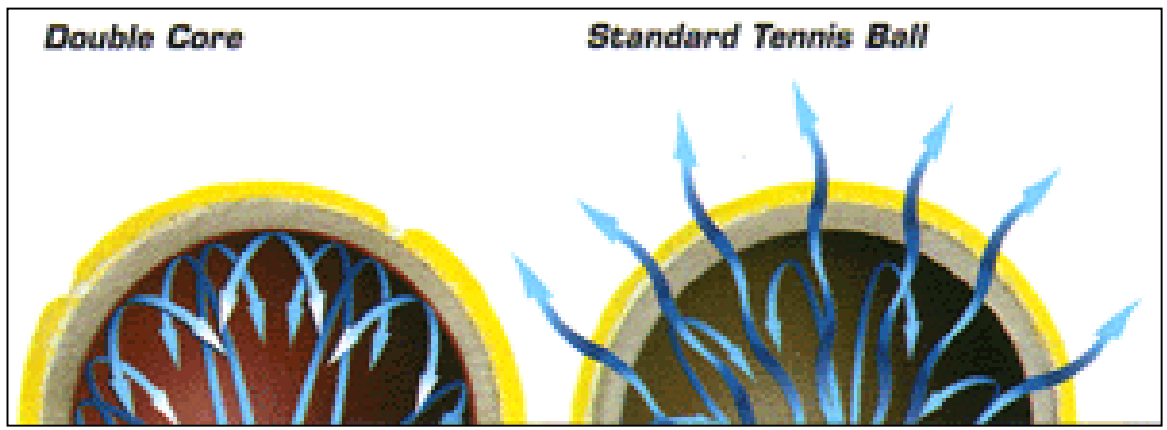


Nano-clay platelets (1 nm thick)
within rubber polymer matrix

Wilson Double Core tennis balls with InMat Air D-Fense:

- better air retention (tortuous path for air to escape)
- more consistent bounce
- longer life

DOUBLE CORE



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Plastic Bottles Gas Barrier

Nanoclay composites
in multi-layer PET bottles

less CO_2 escape and less O_2 absorption:

- increases shelf life, efficiently preserves flavor
- greater light and fire resistance
- stronger mechanical and thermal performance

Honeywell's
Aegis nylon 6
nanocomposites

optically clear if individual clay thickness < λ of visible light

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Portable Water Filtration System

Hydration Technologies X-Pack

Porous plastic bag coated with **nanoclays** to filter water

contaminated water goes in, but only pure water seeps through self-hydrating membrane pouch by osmotic pressure

- filters at 50 nm level (virus, bacteria, parasites)
- light weight
- military and recreational applications

Hydration Technologies' Life-Sustaining Water Filtration Bags Deployed to Katrina Victims

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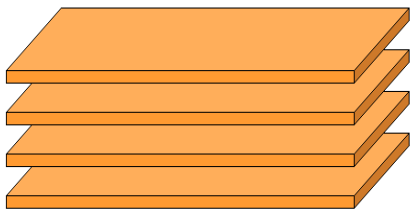
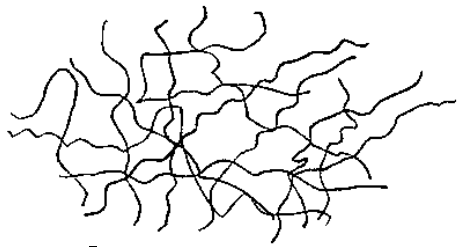
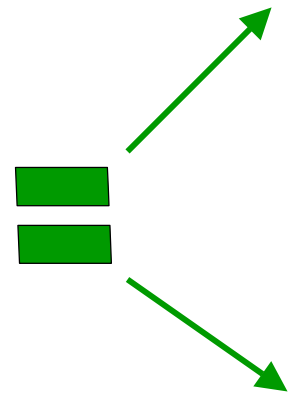
Nano-clay Composites

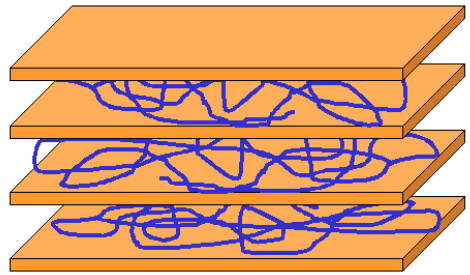
Clay platelets
10 Angstroms thick, but
over 200 times that in width





Polymer
molecular chains bind
clay platelets together





Intercalated Material

Exfoliated Material

very large surface areas of contact between dispersed nano-platelets (1 nm thick) & polymer matrix result in:

- tortuous path for gases to travel through → barrier
- high strength, good toughness, low density → composites

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Step Assists & Car Parts

Chevrolet Impala body side molding, 2004
Hummer H2 SUT cargo bed, 2005

Nanocomposites of clay platelets in polymer matrix

very low loadings of filler (< 5 wt%) needed:

- high strength and stiffness
- less brittle in cold
- low weight
- more recyclable
- wider processing window

Chevrolet Astro & GMC Safari vans step assists, 2002

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Nanotech shopping is educational!

<u>Concepts covered:</u>

Length scales

Surface area/ volume ratio as a function of size

Self assembly

Buckyballs, Nanotubes, Nanoparticles

Biomimicry

Photocatalysis, chemical reactions, hydrophobicity

Optical properties, em spectrum

Mechanical properties

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